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MAIN ARTICLE

Outcomes of cochlear implantation in deaf children of deaf parents: comparative study

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Abstract

Objective: This retrospective study compared the cochlear implantation outcomes of first- and second-generation deaf children.

Methods: The study group consisted of seven deaf, cochlear-implanted children with deaf parents. An equal number of deaf children with normal-hearing parents were selected by matched sampling as a reference group. Participants were matched based on onset and severity of deafness, duration of deafness, age at cochlear implantation, duration of cochlear implantation, gender, and cochlear implant model. We used the Persian Auditory Perception Test for the Hearing Impaired, the Speech Intelligibility Rating scale, and the Sentence Imitation Test, in order to measure participants' speech perception, speech production and language development, respectively.

Results: Both groups of children showed auditory and speech development. However, the second-generation deaf children (i.e. deaf children of deaf parents) exceeded the cochlear implantation performance of the deaf children with hearing parents.

Conclusion: This study confirms that second-generation deaf children exceed deaf children of hearing parents in terms of cochlear implantation performance. Encouraging deaf children to communicate in sign language from a very early age, before cochlear implantation, appears to improve their ability to learn spoken language after cochlear implantation.

Key words: Deafness; Ear, Inner; Cochlear Implantation; Prognosis; Outcomes Research

Introduction

The development of cochlear implantation (CI) to restore stimulation to the inner ear has revolutionised treatment for most deaf children. Factors affecting the outcome of paediatric CI have been the subject of much research. Distinguishing such factors is valuable as it enables researchers to develop more sophisticated CI candidacy criteria, and also to develop more effective intervention programmes to facilitate the auditory, speech and language development of implantees.

Although most deaf children are born into hearing families, deaf children raised in deaf families have been found to out-perform those from hearing families in terms of intelligence and related abilities.[1] Such second-generation deaf children, who learn sign language from their parents as their native language from birth and are hence termed 'native signers', perform better in intelligence tests than their deaf peers with hearing parents.[2–5] They also show significantly better performance of 'theory of mind' tasks in comparison with deaf children from hearing families.[6–13] Furthermore, they show better development of a second, verbal language, and of reading skills, compared with first-generation deaf children.[14]

Deaf children with deaf parents have better reaction time measures, compared with deaf children with hearing parents and also hearing peers.[15] This might be considered a consequence of using sign language as the means of primary communication. Deaf children of deaf parents are more experienced at moving their hands compared with their deaf peers with hearing parents.

Second-generation deaf children are also exposed in early childhood to visual language, which some authors believe to enhance aspects of visual processing.[1,16]

Other findings have indicated greater maturation of the left hemisphere in native signers.[17] This may be due to deaf children of hearing parents having delayed access to communication, compared with second-generation deaf children.[18] Early linguistic experience can lead to successful second language

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learning, even when the first language is sign language and the subsequent second language is a spoken one.[19]

Comparisons of the cognitive features of deaf children raised in deaf families versus those raised in hearing families have been published. However, CI outcomes in these two groups of deaf children have not been compared.

This retrospective study investigated the relationship between parental hearing status and CI outcomes in their deaf children. We compared the speech perception, speech production and language development of deaf children with deaf parents versus those with hearing parents, after CI.

Materials and methods

The study group consisted of seven cochlear-implanted deaf children with deaf parents. This group had the opportunity to acquire Persian sign language from their parents. An equal number of deaf children with normal-hearing parents were selected by matched sampling as a reference group. Participants were matched based on onset and severity of deafness, duration of deafness, age at CI, duration of CI, gender, and implant model. All participants with syndromic deafness and additional disability were excluded from the study. Demographic features of the participants are given in Table I. Participants were selected from 739 prelingually deaf children who underwent CI between 18 to 67 months of age, between 1998 and 2009 in the Iranian cochlear implant centre. All participants had been diagnosed with profound, bilateral, sensorineural hearing loss, within their first year of life.

We used the Persian Auditory Perception Test for the Hearing Impaired, the Speech Intelligibility Rating scale and the Sentence Imitation Test to measure participants' speech perception, speech production and language development, respectively.[20–22]

The Persian Auditory Perception Test for the Hearing Impaired consists of 50 items ranked in 3 levels based on degree of difficulty. The first level has 16 items evaluating auditory awareness, duration, intensity, pitch identification, and identification of words and sentences through suprasegmental information. The second level has 22 items evaluating vowel and consonant perception by segmental information and identification of phonemes, words and phrases, using segmental information in a closed set. The third level has 12 items evaluating comprehension in closed and open sets. The total maximum score for the test is 100. The test's reliability and validity are acceptable: reliability, based on the split half method with Spearman Brown formula and test–retest, is $\alpha = 0.96$ and $\alpha = 0.97$, respectively; and internal consistency, based on the Kuder Richardson formula, is $\alpha = 0.95$. The construct validity of the test is $R = 0.83$. Items in the test were presented by a male speaker in a controlled, live voice mode at an average presentation level of 70 dB SPL in a soundproof room.

The Speech Intelligibility Rating scale quantifies the speech production abilities of deaf children. It is a five-point scale ranging from pre-recognisable words in spoken language to connected speech intelligible to all listeners. The reliability of this scale has been evaluated, and a high rate of agreement found between observers using the scale to assess the speech intelligibility of deaf children after CI. A speech therapist rated each child's performance according to the scale, as directed by predefined guidelines, and as suggested by the authors of the scale.

Sentence imitation is an appropriate indicator of children's language abilities, and is related to other

TABLE I
SUBJECTS' CHARACTERISTICS

Subject no	Age (mth)	Age at CI (mth)	CI durn (mth)	Sex	Implant model
DD group					
1	153	25	128	F	Med-el, Combi 40 +
2	135	59	76	F	Nucleus, Sprint
3	123	29	94	M	Nucleus, Sprint
4	115	40	75	F	Nucleus, Sprint
5	104	33	71	M	Nucleus, Sprint
6	59	47	12	F	Nucleus, Freedom
7	52	37	15	F	Nucleus, Freedom
Mean	105.85	38.57	67.28		
SD	37.74	11.54	41.51		
DH group					
1	147	22	125	F	Med-el, Combi 40 +
2	137	50	87	F	Nucleus, Sprint
3	129	36	93	M	Nucleus, Sprint
4	109	45	64	F	Nucleus, Sprint
5	107	25	82	M	Nucleus, Sprint
6	65	45	20	F	Nucleus, Freedom
7	51	33	18	F	Nucleus, Freedom
Mean	106.42	36.57	69.85		
SD	36.25	10.65	39.21		

No = number; mth = months; CI = cochlear implantation; durn = duration; DD = deaf children with deaf parents; F = female; M = male; SD = standard deviation; DH = deaf children with hearing parents

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language measures.[22] In this study, we used the Sentence Imitation subtest of the Persian Language Development Test.[23] This subtest includes 30 items and assesses syntax expression. The examiner reads each sentence; the child must listen to it and then repeat the sentence after the examiner, immediately.

Participants were assessed four times: at the first implant fitting, at 6 and 12 months following the first fitting, and at the time of gathering data for the current study. Data were expressed as means and standard deviations. The performance scores of deaf children with deaf parents were compared with those of deaf children with hearing parents. Non-parametric analyses of variance for repeated measurements (Friedman tests), with time as a factor, were performed for the Persian Auditory Perception Test for the Hearing Impaired, the Speech Intelligibility Rating test and the Sentence Imitation Test. Mann–Whitney U tests were applied in order to detect significant differences between deaf children with deaf parents and those with hearing parents. The Statistical Package for the Social Sciences version 16.0 for Windows software program (SPSS Inc, Chicago, Illinois, USA) was used for statistical analysis.

Results

There were no significant differences ($p < 0.01$) between deaf children with deaf parents and those with hearing parents in terms of chronological age, age at CI, sex, duration of implant and implant model (Table I).

Deaf children with deaf parents

Results indicated a significant improvement in scores for the Persian Auditory Perception Test for the Hearing Impaired, the Speech Intelligibility Rating scale and the Sentence Imitation Test, over time, for deaf children with deaf parents compared with those with hearing parents ($p < 0.000$; Friedman test as non-parametric analyses of variance for repeated measurements with time as a factor).

In these children, the mean (standard deviation) scores for the Persian Auditory Perception Test for the Hearing Impaired, the Speech Intelligibility Rating scale and the Sentence Imitation Test were respectively 1.42 (1.61), 1 (0) and 0 at first fitting, increasing to 75.58 (20.81), 4.85 (0.37) and 15.14 (5.42) over a mean period of 67.28 months (Table II).

Deaf children with hearing parents

For the deaf children with hearing parents, the mean (standard deviation) scores for the Persian Auditory Perception Test for the Hearing Impaired, the Speech Intelligibility Rating scale and the Sentence Imitation Test were respectively 1.85 (1.95), 1.14 (0.37) and 0 at first fitting, increasing to 58.85 (21.70), 3.57 (0.97) and 6.71 (4.68) over a mean period of 69.85 months (Table II). There was a significant improvement in all scores over time ($p < 0.000$).

TABLE II
SUBJECTS' TEST RESULTS

Time point	PAPT/HI score			SIR score			SIT score		
	DD	DH	*p*	DD	DH	*p*	DD	DH	*p*
1st fitting	1.42 (1.61)	1.85 (1.95)	0.07	1.00 (0.00)	1.14 (0.37)	0.71	0.00 (0.00)	0.00 (0.00)	1.00
6 mth post-CI	40.42 (14.22)	22.28 (9.58)	0.01*	2.28 (0.75)	1.28 (0.48)	0.02*	1.57 (1.27)	0.28 (0.48)	0.02*
12 mth post-CI	66.42 (16.44)	34.42 (11.98)	0.00*	3.85 (0.69)	2.00 (0.57)	0.00*	6.00 (3.10)	0.85 (1.21)	0.00*
Last test	75.85 (20.81)	58.85 (21.70)	0.09	4.85 (0.37)	3.57 (0.97)	0.01*	15.14 (5.42)	6.71 (4.68)	0.01*
p	0.000†	0.000†		0.000†	0.00†		0.000†	0.004†	

Data represent means (standard deviations) unless otherwise specified. *$p < 0.05$, deaf children with deaf parents (DD) *vs* deaf children with hearing parents (DH); †$p < 0.05$, comparing different time points. PAPT/HI = Persian Auditory Perception Test for the Hearing Impaired; SIR = Speech Intelligibility Rating scale; SIT = Sentence Imitation Test (subtest of Persian Language Development Test); mth = month; CI = cochlear implantation

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Comparison between groups

Figures 1, 2 and 3 show test scores for the two groups of deaf, cochlear-implanted children over time.

The children's speech perception was measured using the Persian Auditory Perception Test for the Hearing Impaired at first implant fitting, at 6 and 12 months after CI, and at final testing; mean scores were respectively 1.42, 40.42, 66.42 and 75.85 for deaf children with deaf parents, versus 1.85, 22.28, 34.42 and 58.85 for deaf children with hearing parents. Significant differences were found between the groups (using the Mann–Whitney U test) at 6 months ($p < 0.01$) and 12 months ($p < 0.00$), but there were no significant differences at first fitting ($p < 0.07$) or at final testing ($p < 0.09$). This could indicate that, although deaf children with deaf parents show more rapid development in speech perception after CI, in the long term both groups are relatively equal in this respect. The fact that there was no observed difference between the two groups at first fitting indicated that the initial matched selection had been successful.

The children's speech intelligibility was measured using the Speech Intelligibility Rating scale at first fitting, at 6 and 12 months after CI, and at final testing; mean scores were respectively 1, 2.28, 3.85 and 4.85 for deaf children with deaf parents, versus 1.14, 1.28, 2 and 3.57 for deaf children with hearing parents. Significant differences were found between the groups (using the Mann–Whitney U test) at 6 months ($p < 0.02$), 12 months ($p < 0.00$) and final testing ($p < 0.01$).

The children's production of spoken sentences was measured using the Sentence Imitation Test at first fitting, at 6 and 12 months after CI, and at final testing; mean scores were respectively 0, 1.57, 6 and 15.14 for deaf children with deaf parents, versus 0, 0.28, 0.085 and 6.71 for deaf children with hearing parents. Significant differences were found between the groups (Mann–Whitney U test) at 6 months ($p < 0.02$), 12 months ($p < 0.00$) and final testing ($p < 0.01$).

In brief, results indicated that the implant performance of deaf children with deaf parents exceeded that of deaf children with hearing parents.

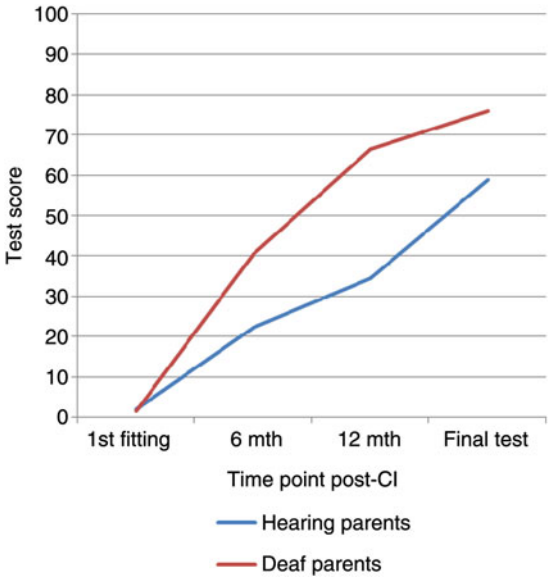

FIG. 1

Results for the Persian Auditory Perception Test for the Hearing Impaired in deaf children with hearing parents and those with deaf parents. Mth = months; CI = cochlear implantation

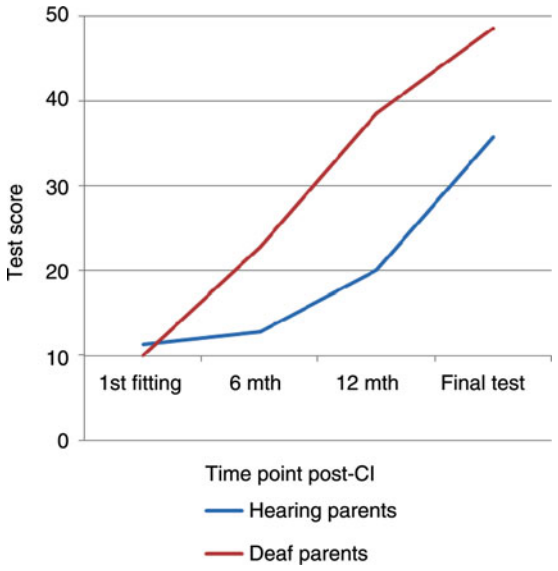

FIG. 2

Results for the Speech Intelligibility Rating scale in deaf children with hearing parents and those with deaf parents. Mth = months; CI = cochlear implantation

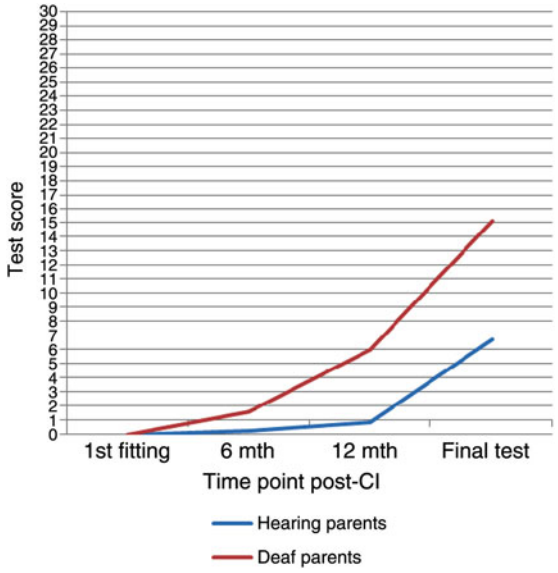

FIG. 3

Results for the Sentence Imitation Test in deaf children with hearing parents and those with deaf parents. Mth = months; CI = cochlear implantation

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Discussion

This study aimed to compare the CI outcomes of deaf children with deaf parents versus deaf children with hearing parents. Our findings indicated that the deaf children with deaf parents out-performed those with hearing parents as regards CI outcomes. This difference in outcomes occurred despite the fact that all our study participants were homogeneous regarding onset and severity of deafness, duration of deafness, age at CI, duration of CI, gender, and implant model.

Earlier studies have indicated that deaf children with deaf parents perform better than deaf children with hearing parents in intelligence tests, theory of mind tasks, second language development, reading skills, reaction time and left hemisphere maturation.[1–17] When the results of the numerous studies summarised above are combined with the findings of the current study, the resulting evidence indicates that deaf children with deaf parents have enhanced communication abilities compared with their peers with hearing parents. This could be related to the earlier onset of communication between deaf children and deaf parents. Deaf parents deal better with the early learning needs of their deaf children, compared with hearing parents.[2,24] In addition, learning the visiospatial grammar of sign language improves the visual and spatial skills of deaf children.[25] Exposure to visual communication promoting strategies begins at birth in deaf families: deaf parents communicate with their deaf child through gestures and signs immediately after birth. Deaf children do not have access to adequate auditory information before CI; therefore, the visual part of communication is critical for them. Deaf parents develop communication with their deaf children using eye contact, facial expression, body language, speech reading and especially sign language. Deaf parents of deaf children can sustain communication in a visual mode, waiting for their child's visual attention to be drawn, in order to communicate. This communication practice is not a natural habit for hearing parents, because they use an aural-visual mode of communication.[26] Therefore, deaf children with deaf parents acquire language in a natural way.

- **Deaf children with deaf parents out-perform deaf children with hearing parents in cochlear implantation (CI) performance**
- **Deaf children should be encouraged to use sign language from a very early age (pre-CI)**
- **This improves their post-CI ability to learn spoken language**

In addition, earlier studies indicate that the age of first language acquisition can be a determining factor in the success of both first and second language acquisition. Early acquisition of sign language as the child's first language supports later learning of a spoken language.[19,27]

Conclusion

These study findings confirm that second-generation deaf children exceed deaf children of hearing parents in terms of CI performance. We may conclude that encouraging deaf children to communicate in sign language at a very early age, before CI, improves their ability to learn spoken language after CI.

We recommend that future studies compare greater numbers of deaf children with deaf parents versus deaf children with hearing parents, when assessing CI outcomes.

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